3.13 GEOLOGY AND SOILS

This section describes existing geologic conditions in the five study regions and analyzes the potential geological impacts of each alternative and proposed HST alignment option. This analysis focused on potential impacts related to seismic hazards; landslide hazards; locations of oil and gas fields, geothermal fields, and mineral resource sites, and on bedrock and other conditions that could affect excavation.

3.13.1 Regulatory Requirements and Methods of Evaluation

A. REGULATORY REQUIREMENTS

A number of state regulations apply to geologic hazards and engineering geologic practice. The following paragraphs summarize key regulatory provisions; more detailed discussion is deferred to project-level environmental documentation because these regulations, if applicable, relate to site-specific conditions and thus would be applied as appropriate at the project level rather than the program level.

Principal state guidance relating to geologic hazards is contained in the Alquist-Priolo Act (P.R.C. § 2621 *et seq*.), and in the Seismic Hazards Mapping Act of 1990 (P.R.C. § 2690–2699.6). The Alquist-Priolo Act prohibits the location of most types of structures for human occupancy across the active traces of faults in earthquake fault zones shown on maps prepared by the state geologist, and regulates construction in the corridors along active faults (earthquake fault zones). The Seismic Hazards Mapping Act of 1990 focuses on hazards related to strong ground shaking, liquefaction, and seismically induced landslides. Under its provisions, the state is charged with identifying and mapping areas at risk of strong ground shaking, liquefaction, landslides, and other corollary hazards, and the maps are to be used by cities and counties in preparing their general plans and adopting land use policies in order to reduce and mitigate potential hazards to public health and safety.

Site-specific geotechnical investigations may be prepared to provide a geologic basis for the development of appropriate construction design for proposed projects, including mitigation/ remediation of geologic hazards where this is possible. Geotechnical investigations typically assess the bedrock and Quaternary geology, the geologic structure, the soils, and the previous history of excavation and fill placement on and in the vicinity of the site for a proposed project. They may also address the requirements of the Alquist-Priolo Act and the Seismic Hazards Mapping Act.

Pursuant to the Surface Mining and Reclamation Act (P.R.C. § 2710 *et seq*.), the State Mining and Geology Board identifies in adopted regulations areas of regional significance that are known to contain mineral deposits judged to be important in meeting the future needs of the area. (See P.R.C. § 2726 and 2790; Title 14 C.C.R. 3550, *et seq*.) The State Mining and Geology Board also adopts state policy for the reclamation of mined lands and certifies local ordinances for the approval of reclamation plans as being consistent with state policies (P.R.C. § 2755–2764, 2774 *et seq*.).

B. METHOD OF EVALUATION OF IMPACTS

To evaluate potential impacts related to geology and soils, each alternative was ranked for potential seismic hazards (ground shaking and ground failure potential), surface rupture hazard (number of active fault crossings), slope instability, areas of difficult excavation, presence of oil/gas/geothermal fields (presence of the resource and/or production facilities), and presence of economic mineral resources. The analysis was performed generally on the basis of existing data available in geographic information systems (GIS) format as opposed to detailed site investigations. The geologic data provided in this section are intended for planning purposes and are not intended to be definitive for specific sites. Alignments were evaluated by the regional team technical leads as having high, medium, or low potential for geologic impacts based on the number of geologic constraints identified.

Airports, stations, and other facilities were evaluated as having high or low potential for geologic impacts, based on the number of geologic constraints identified. These rankings made it possible to provide a rough comparison of the potential geologic constraints affecting each alternative and each alignment.

The following paragraphs describe the ranking process. Table 3.13-1 summarizes the ranking criteria for potential geologic and soils impacts.

Table 3.13-1
Ranking System for Comparing Impacts Related to Geology/Soils/Seismicity

Impact Ranking	Seismic Hazards (% of Length)	Active Fault Crossings (Number of Crossings)	Slope Instability (% of Length)	Difficult Excavation (% of Length)	Oil and Gas Fields (% of Length)	Mineral Resources (Present or Not Present)
Alignments						
High	>50	2+	>10	>25	>20	>20
Medium	10–50	1	5–10	10–25	10–20	10–20
Low	<10	0	<5	<10	<10	<10
Airports/Stations/Facilities						
High	Present	Present	Present	Present	Present	Present
Low	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present

Seismic Hazards

Seismic hazards that could potentially constrain the design of proposed facilities were evaluated on the basis of potential for strong ground motion and potential for liquefaction. Areas potentially subject to strong ground motion were defined for this program-level study as areas where peak horizontal ground accelerations in an earthquake may exceed 0.50g (i.e., areas where peak horizontal ground acceleration may exceed 50% of the acceleration due to gravity) as mapped by the California Geological Survey (formerly the California Division of Mines and Geology) (State of California 1999). This acceleration is used to calculate the horizontal force a structure may be subjected to during and earthquake. For this analysis, liquefaction was conservatively assumed to be possible in all areas where peak ground accelerations could exceed 0.30g, except for areas mapped as underlain by bedrock. Where groundwater levels were not known from existing literature, they were conservatively assumed to be high, contributing to increased potential for liquefaction.

The ranking system for impacts related to seismic hazards used the percentage of each potential alignment within strong ground motion zones and/or potentially liquefiable zones. Station and airport sites were compared by determining whether any portion of the proposed station site would be within a strong ground motion zone or potentially liquefiable zone.

- Alignments: High, medium, or low, based on percentage of alignment length in strong ground motion zones plus the percentage of length in potentially liquefiable zones.
- Stations/airports: High if any part of the site is within a strong ground motion zone or potentially liquefiable zone; otherwise, low.

Potential for Surface Rupture (Active Fault Crossings)

Surface rupture hazard was evaluated based on whether any portion of a project alignment or facility would be located within 200 ft (62 m) of the mapped trace of any fault with known or inferred movement during Quaternary time (the past 1.6 million years). If any portion of a proposed alignment or potential facilities site was within 200 ft (62 m) of a Quaternary fault, it was identified as crossing an active fault trace. As described below, the State of California defines active faults as those that show evidence for movement in the last 11,000 years. Because of the extreme disruption of transit facilities that can result from surface fault rupture, this analysis deliberately adopted a conservative criterion for the assessment of surface rupture hazard and included potentially active faults, those with known or inferred movement over Quaternary time.

The ranking system for impacts related to surface rupture hazard was based on the number of active fault crossings identified.

- Alignments: High, medium, or low, based on number of active (recent or Quaternary) fault crossings.
- Stations/airports: High if any part of the site is within 200 ft (60 m) of an active (recent or Quaternary) fault; otherwise, low.

Slope Instability

Slope stability was evaluated based on the geologic formations or units present along each alignment and at each facilities site, as shown in statewide mapping compiled by Jennings (1977, 1991). Each of the mapped geologic units was assigned a rating for inferred slope stability, based primarily on lithology (physical characteristics of the rock formation) and age. This approach allowed the identification of areas at risk for slope instability. A conservative 200-ft (60-m) buffer was included around each identified area of instability.

The ranking system for impacts related to slope instability was based on the percentage of each alignment within potentially unstable zones. Station and airport sites were compared by determining whether any portion of the site is within an area of potential slope instability.

- Alignments: High, medium, or low, based on percentage of alignment length in potentially unstable zone.
- Stations/airports: High if any part of the site is within a potentially unstable zone; otherwise, low.

Difficult Excavation

Areas of potentially difficult excavation were identified based on bedrock geologic characteristics in combination with the presence of faults of any age, based on statewide mapping compiled by Jennings (1977, 1991) and information from selected 1:250,000-scale geologic map sheets for the study regions published by the California Geological Survey. Each fault crossing was conservatively assumed to be approximately 600 ft (185 m) wide. Geologic cross-sections were prepared to assess subsurface tunneling conditions along proposed HST tunnel segments.

The ranking system for impacts related to difficulty of excavation was based on the percentage of each alignment where excavation would be required within identified areas of difficult excavation. Stations and airport sites were compared by determining whether any portion of the site is within an identified area of difficult excavation.

- Alignments: High, medium, or low, based on percentage of surface segments in hard rock plus percentage of tunnel segments within fault zones.
- Stations/airports: High if any part of the site is within a hard rock zone or fault zone; otherwise, low.

Oil, Gas, and Geothermal Fields
Areas where the presence of oil, gas, and geothermal resources could constrain project construction or operation were identified on the basis of published resource maps produced by the California Department of Conservation's Division of Oil, Gas, and Geothermal Resources (California Department of Conservation 2001a, 2001b).

The ranking system for impacts related to oil, gas, and geothermal fields was based on the percentage of each proposed alignment within identified oil and gas or geothermal field areas. Station and airport sites were compared by determining whether any portion of the proposed site is within a mapped oil, gas, or geothermal field areas.

- Alignment: High, medium, or low, based on percentage of alignment length within mapped oil and gas plus geothermal fields.
- Stations/airports: High if any part of the site is within a mapped oil, gas, or geothermal field; otherwise, low.

Mineral Resources
Areas where the project could affect mineral resource extraction (primarily sand and gravel deposits) were identified on the basis of reports and published maps by the United States Geologic Survey, and California Geologic Survey.

The ranking system for mineral resources impacts was based on the number of mineral resources sites intersected by each alignment. Station and airport sites were compared by determining whether any portion of the site is within a mineral resource area. The potential value of mineral resources varies with time with demand for the resource. Thus, evaluation of specific sites for relative importance was not considered for this program-level study.

- Alignments: High, medium, or low, based on number of mapped resources within 200 ft (60 m) of a mineral resource area.
- Stations/airports: High if any part of the site is within 200 ft (60 m) of a mineral resource area; otherwise, low.

3.13.2 Affected Environment

A. STUDY AREA DEFINED

The study area for geology and soils is defined as the corridor extending 200 ft (60 m) on each side of the alignment centerlines, and a 200-ft (60-m) radius around each station or airport site. This distance incorporates all cross-sections with the exception of deep cuts and fills. As described in *Method of Evaluation of Impacts* above, alternatives were compared based on the number of sites with potential geologic or soils impacts per alternative, which depends on the length and location of the alignment; broadening the study area to include the entire width of deep cut-and-fill sections would not change the results of the comparison.

B. GENERAL DISCUSSION OF GEOLOGY AND SOILS

The following sections describe key project constraints related to geology and soils.

Seismic Hazards
Seismic hazards are generally classified in two categories: *primary seismic hazards* (surface fault rupture and ground shaking) and *secondary seismic hazards* (liquefaction and other types of seismically induced ground failure, along with seismically induced landslides).

Primary: *Surface fault rupture*, or ground rupture, occurs when an active fault ruptures at depth to produce an earthquake, and the rupture propagates to the ground surface. Surface rupture can also occur as a result of slow, gradual motion referred to as *fault creep*. An area's potential for ground rupture is assessed based on the displacement history of the area's faults. Two categories of faults have been defined by the State of California in Special Publication 42 (Hart and Bryant 1997). *Active faults* are those that are known or inferred to have experienced movement in the past 11,000 years and are considered to have a high potential for future ground rupture. *Potentially active*[1] faults are those that are not known to have experienced movement in the past 11,000 years but have moved during Quaternary time (the past 1.6 million years). These faults may also pose a surface rupture hazard, but the hazard is more difficult to evaluate. For the purpose of this study, both active and potentially active faults were evaluated, and considered active faults in subsequent sections.

Ground shaking occurs in response to the release of energy during an earthquake. The energy released travels through subsurface rock, sediment, and soil materials as seismic waves, which result in motion experienced at the ground surface.

Secondary: *Liquefaction* and other types of seismically induced ground failure reflect loss of strength and/or cohesion when earth materials are subjected to strong seismic ground shaking. Earthquakes can also trigger landslides where slopes are prone to failure because of geologic conditions or because of modifications during construction.

Surface fault rupture, ground shaking, and seismically induced ground failure all can result in substantial damage to structures. Thorough assessment of the existing hazard combined with appropriate design and construction can reduce the potential for damage substantially.

Unstable Slopes

Slopes are considered unstable (prone to failure or landslides) when soil or rock strength is insufficient to resist gravitational forces or other loads. Slope instability can occur naturally due to factors such as fracture patterns, soil saturation, or steep slopes. Slope failure can also be triggered by seismic activity or by improperly designed construction.

If slope instability is not adequately characterized and mitigated during design and construction, it can cause severe damage to surface and near-surface improvements as well as risks to public safety. However, slope instability can generally be addressed with planning and design.

Areas of Difficult Excavation

Subsurface geologic conditions will largely determine the ease or difficulty of excavation, which will in turn indicate the appropriate excavation technique for use in various areas. For instance, hard unfractured bedrock may be difficult to excavate using bulldozers and other earthmoving equipment, or too resistant to tunneling using a tunnel boring machine; in these areas, blasting may be required. On the other hand, fractured rock that contains groundwater can also be difficult to excavate using tunneling methods. Faulted material can pose an additional challenge by contributing to instability at the tunnel face.

Geological Resources

Geological resources in California include oil and gas fields, geothermal fields, and a wide range of mineral resources. The principal constraint associated with oil, gas, geothermal, and mineral resources is the need for planning to ensure that construction of new facilities would not conflict with the removal of economically important resources and would avoid known problem areas to

[1] The term "potentially active" is under review for alternative nomenclature by California Geologic Survey.

the extent feasible. In addition, the presence of even small (noneconomic) quantities of oil or gas in the subsurface can pose toxic or explosive hazards during construction, requiring specific precautions, and may also necessitate special designs and monitoring during the operation of subsurface structures such as subway tunnels. Similarly, certain mineral resources, such as serpentine (the source of natural asbestos) can result in hazardous working conditions if not properly managed.

C. GEOLOGY AND GEOMORPHOLOGY BY REGION

Appendix 3.13-A contains tables summarizing the geologic constraints in each of the five study regions. The following paragraphs provide an overview of key geomorphologic features in each region, based on Norris and Webb's (1990) overview of California's geomorphic provinces and information from topographic maps published by the U.S. Geological Survey.

Bay Area to Merced

This region includes central California from the San Francisco Bay Area (San Francisco and Oakland) south to the Santa Clara Valley and east across the Diablo Range to the Central Valley. The Bay Area to Merced region spans two of California's geomorphic provinces: the Coast Ranges province and the Great Valley province.

The Coast Ranges uplift consists of generally northwest-trending ridges that form a rugged barrier between the Pacific Coast and inland California. The valley occupied by San Francisco Bay, bordered by the Diablo Range and East Bay Hills on the east and the Santa Cruz Mountains on the west, is one of several fault-bounded valleys within the Coast Ranges; other important regions of low elevation near the study area include the Salinas, Napa, and Sonoma Valleys.

The Great Valley province comprises a large, elongated north-trending valley situated between the Coast Ranges on the west and the Sierra Nevada on the east. Much of the Great Valley is at elevations near sea level (Norris and Webb 1990). The valley is structurally controlled, with faults occurring at the boundaries between valley and mountain range.

Sacramento to Bakersfield

This region of central California includes a large portion of the Central Valley (San Joaquin Valley) from Sacramento south to Bakersfield. Relatively uniform, gentle terrain that typifies the interior of California's Great Valley geomorphic province characterizes this region. As described above, the Great Valley province consists of an elongate north-trending valley bordered by the Sierra Nevada and the Coast Ranges (Norris and Webb 1990).

Bakersfield to Los Angeles

This region of southern California encompasses the southern portion of the Central Valley south of Bakersfield, the mountainous areas between the Central Valley and the Los Angeles basin, and the northern portion of the Los Angeles basin from Sylmar to downtown Los Angeles. The Bakersfield to Los Angeles region includes portions of three major geomorphic provinces: Great Valley, Mojave, and Transverse Ranges. Consequently, terrain in this region is highly variable. From the southern end of the San Joaquin Valley, the proposed alignments would climb several thousand feet to cross the rugged Tehachapi Mountains. They would descend across the westernmost portion of the Mojave province, and would climb again to cross the San Gabriel Mountains before descending into the Los Angeles basin. The Los Angeles basin is a fault-bounded depression within the Transverse Ranges province, which was named for its westerly structural and geomorphic grain, transverse to the dominant northerly-northwesterly fabric of California landscapes (Norris and Webb 1990).

Los Angeles to San Diego via Inland Empire
This region of southern California includes the eastern portion of the Los Angeles basin (Transverse Ranges) from downtown Los Angeles east to the Riverside and San Bernardino areas and south to San Diego generally along the I-215 and I-15 corridors. This region is located in the Los Angeles basin and the Peninsular Ranges province. The Los Angeles basin is bounded by several westerly-trending ranges, including the Elysian, Repetto, Puente, and San Joaquin Hills and the Santa Ana Mountains. The Peninsular Ranges province is characterized by a series of northwest- to west-northwest-trending fault-bounded mountain ranges.

Los Angeles to San Diego via Orange County
This region includes the western portion of the Los Angeles basin between downtown Los Angeles and Los Angeles International Airport (LAX) and the coastal areas of southern California between Los Angeles and San Diego, generally following the existing Los Angeles to San Diego via Orange County (LOSSAN) rail corridor. The LOSSAN route follows a coastal corridor that traverses parts of two geomorphic provinces: the Transverse Ranges and Peninsular Ranges. Key features of this southern region include spectacular coastal cliffs.

3.13.3 Environmental Consequences

A. EXISTING CONDITIONS COMPARED TO NO PROJECT ALTERNATIVE

Existing conditions describes transportation conditions as of 2003. The No Project Alternative includes existing transportation infrastructure plus all planned, approved, and funded projects that can reasonably be expected to be in operation by 2020. This analysis assumed that existing major infrastructure (bridges, for example) was designed, has been retrofitted, or is currently scheduled to be retrofitted to meet current design standards for seismic safety and other geologic constraints, and that future projects included in the No Project Alternative would incorporate similar safeguards as part of the development, design, and construction process. However, it is not possible to eliminate or mitigate all geologic hazards through design and construction. Some types of geologic hazards (seismic hazards in particular) are also unpredictable. While it is difficult to evaluate the change in hazards (potential for geologic impacts) between existing conditions and No Project conditions, it can be assumed that some improvements in technology and materials as well as more stringent design codes will be implemented in the next 20 years to address seismic design of new structures. Thus the No Project Alternative would be somewhat improved from the existing conditions, but existing geologic risks were assumed to be representative of geologic risks under the No Project Alternative.

B. NO PROJECT ALTERNATIVE COMPARED TO MODAL AND HIGH-SPEED TRAIN ALTERNATIVES

This analysis focused on comparing the difference in impacts anticipated with the proposed Modal and HST Alternatives, using 2020 No Project conditions as a baseline.

As shown in Table 3.13-2, geologic constraints would be similar for the proposed Modal and HST Alternatives. They include the following.

- Active fault crossings.
- Potential for strong seismic ground shaking.
- Unstable slopes.
- Difficult excavation of tunnels and deep cuts.
- At-grade construction over problem soils.

Active seismicity represents a key constraint on design and construction for both the Modal and HST Alternatives. Portions of both the Modal and HST Alternatives would require special design, including additional structural ductility and redundancy to withstand severe ground shaking as well as the potential for liquefaction and/or other types of seismically induced ground failure. Conceptual alignments have been laid out so that the proposed HST Alternative would cross major faults at grade; nonetheless, active fault crossings would require special designs to minimize potential damage to the rail lines and other infrastructure as a result of surface fault rupture and surface disruption associated with fault creep. Modal Alternative designs would be subject to similar requirements.

Construction of mountain crossings for both the Modal and HST Alternatives would be constrained by existing unstable slopes and areas of difficult excavation. The tunnels proposed under the HST Alternative would pose additional design and construction issues because of difficult excavation conditions. The Modal Alternative would not require tunnel construction, so impacts related to difficulty of excavation would be less under the Modal Alternative. In the LOSSAN segment, however, tunnel construction under the HST would result in lower impacts on coastal geology because impacts on the stability of coastal bluffs would be reduced.

Potential geologic impacts that are categorized as high should not be regarded as precluding construction of an alternative or an alignment option, or as necessarily indicating that these would be potentially significant impacts. Rather, they identify aspects of project design where additional study would be needed and where engineering and design effort would be required to avoid or mitigate the impacts.

Table 3.13-2
Summary of Geology Potential Impact Rankings by Alternative and Segment

		Bay Area to Merced		Sacramento to Bakersfield		Bakersfield to Los Angeles		Los Angeles to San Diego (via Inland Empire)		Los Angeles to San Diego (via Orange County)	
Category	**Impact**	**Modal**	**HST**	**Modal**	**HST**	**Modal**	**HST**	**Modal**	**HST**	**Modal**	**HST**
Seismic hazards	Potential risk to worker and public safety due to collapse or toppling of partially constructed or completed facilities during strong earthquakes. Potential risk to public safety due to automobile accidents/interruption of service due to derailment caused by ground motion during strong earthquakes. Damage to facilities due to secondary hazards over soft or filled ground.	H	M	L	L	H	H	H	H	H	H
Active fault crossings	Potential risk to worker or public safety due to ground rupture along active faults. Potential risk to public safety due to damage to highway or airport/interruption of service due to derailment by ground rupture along active faults.	M–H	H	H	L	H	M–H	H	H	M	M
Slope stability	Potential risk to worker or public safety due to failure of natural and/or construction cut slopes or retention structures.	L–H	L–M	L	L	L	L	L	L	L	M
Difficult excavation	Potential cost and duration of surface or tunnel excavations during construction.	L–M	M	L	L	L	M	H	M–H	L	L–M
Oil and gas fields	Potential migration of potentially explosive and/or toxic gases into subsurface facilities.	L	L	L	L	L	M	L	M	L	L
Mineral resources	Potential project costs and delays due to potential impacts on existing mineral resource areas and facilities, including potential remediation.	L–M	L–M	L	M	L	L	H	M	L	L

H = High impact.
M = Medium impact.
L = Low impact.

3.13.4 Comparison of Alternatives by Region

A. BAY AREA TO MERCED

Modal Alternative

In the Bay Area to Merced region, the majority of the Modal Alternative alignments are located in areas of potentially strong ground shaking and, to a lesser extent, areas potentially subject to liquefaction and/or other types of seismically induced ground failure. Active fault crossings would be a concern along I-80 from I-880 to I-5, along I-580 from I-880 to I-5, and along SR-152 from US-101 to I-5. Overall, the Modal Alternative ranked high with respect to seismic hazards, with the exception of the segment along SR-152 from SR-99 to I-5.

Slope stability would be a major consideration where the alignment would require widening of existing highway cuts along SR-152 through the Diablo Ranges. However, the potential for slope stability impacts is low along the remainder of the Bay Area to Merced modal alignments.

Areas where hard rock may be difficult to excavate occur in mountain crossings along SR-15, I-80, and I-580.

High-Speed Train Alternative

In the Bay Area to Merced region, the majority of the HST alignments are located in areas of potentially strong ground motion, and to a lesser extent, areas potentially subject to liquefaction and/or other types of seismically induced ground failure (Figure 3.13-1). Active fault crossings would also be a concern along I-580 from I-880 to I-5 and along SR-152 from US-101 to I-5. Overall, the HST Alternative ranked medium in this region with respect to seismic hazards.

All of the proposed HST alignment alternatives that cross the Diablo Range traverse steep and potentially unstable slopes where the proposed alignment would be at grade or in cuts into slopes. There would be little to no concern about slope stability where the alignments cross the nearly flat topography of the San Francisco Bay margin, the Santa Clara Valley, and the Central Valley. In addition, considering the lengths of the alignments, the potential for slope stability impacts is low through the Diablo Range.

High-Speed Train Alignment Options Comparison

The most likely areas of difficult underground excavation would be the Diablo Range crossings where rocks of the Franciscan Complex are highly variable and include some rock units that are typically hard and fracture zones are common. The proposed tunnel options are all through Franciscan rock.

B. SACRAMENTO TO BAKERSFIELD

Modal Alternative

In the Sacramento to Bakersfield region, the Modal Alternative alignments are ranked medium and high for seismic hazards. Along the western edge of the Central Valley, portions of the I-5 alignment between I-5/I-580 near Tracy in the north and Kettleman City in the south (Stockton to Modesto, Modesto to Merced, and Merced to Fresno corridors) are subject to strong ground shaking (0.7g), as they are along the west side of the Central Valley, near the coastal ranges and in closer proximity to active faults than the HST alternative.

High-Speed Train Alternative

Seismic hazards, including ground motion, liquefaction, and other seismically induced ground movement, are considered relatively minor for the HST Alternative alignments in the Central

Valley. All of the alignments are located in regions ranked low for seismic ground shaking, with the exception of the southern end of the corridor (Bakersfield area), where predicted ground motion is slightly higher but is not expected to exceed 0.5g.

High-Speed Train Alignment Options Comparison

Oil and gas fields would potentially affect all of the following proposed HST alignment segments, as they would the Stockton Downtown Station, Bakersfield Airport Station, and Bakersfield Golden State Station sites. Because the length of the alignment through the oil and gas fields would be relatively short, the overall rankings were all low for impacts due to oil and gas.

Mineral resources provide a potential means to distinguish proposed alignments in parts of the Central Valley. The following alignments and sites ranked high for potential impacts related to mineral resources: Sacramento Downtown Valley station site, Sacramento Power Inn Road station site, and all Sacramento to Stockton alignment options. The presence of mineral resources (typically sand and gravel deposits) is most significant in the Sacramento area but would potentially impact all HST alignment options in the Sacramento to Stockton corridor to some extent.

C. BAKERSFIELD TO LOS ANGELES

Modal Alternative

In the Bakersfield to Los Angeles region, the Modal Alternative is considered to have high potential for impacts related to seismic hazards and fault crossings. With the exception of I-5 from Burbank to Los Angeles Union Station (LAUS), all Modal Alignment segments cross at least one Quaternary fault. Approximately seven active faults, including the Garlock and San Andreas, cross the segment of I-5 that extends between SR-99 and SR-14. The segment of SR-14 between Palmdale and I-5 has approximately five fault active crossings, including the San Andreas.

High-Speed Train Alternative

The HST Alternative alignment options in the Bakersfield to Los Angeles region are considered to have high potential for impacts related to seismic hazards (Figure 3.13-2). In addition, tunneling proposed with the HST Alternative would result in higher design, construction, and operational costs than at-grade construction. Six faults intersect the I-5 Tehachapi corridor, which extends from Wheeler Ridge to San Fernando, and seven faults cross the Soledad Canyon corridor. With regard to active fault crossings, the HST Alternative is ranked low to medium.

High-Speed Train Alignment Options Comparison

All proposed HST alignments through the Tehachapi Mountains would encounter at least four major fault crossings. The most significant crossings would include the San Andreas and the Garlock faults, which are capable of generating large earthquakes (over magnitude 7). The alignment would be designed to cross these faults at grade. Because the impact is expected to be nearly equivalent for these alignments, there is no significant difference between the I-5, SR-58, SR-138, and Wheeler Ridge alignments with regard to fault crossings.

D. LOS ANGELES TO SAN DIEGO VIA INLAND EMPIRE

Modal Alternative

The Modal Alternative is considered to have high potential for impacts related to relatively frequent earthquake activity and the presence of the following faults: the San Jose fault at I-10 in Pomona, the southern San Bernardino fault at I-10 in San Bernardino, and the Temecula fault at I-15 in Temecula. Difficult excavation for cut slopes in hard rock formations would also be a concern in this region.

High-Speed Train Alternative
Several active faults are located in the immediate vicinity of the proposed HST segments and the HST stations; consequently, this alternative ranked high for seismic hazards. The significant faults include the Elysian Park, Rialto-Colton-Claremont, San Jacinto, Murrieta Hot Springs, Whittier-Elsinore, and Newport-Inglewood-Rose Canyon faults. In addition, three active faults cross the proposed HST segments in this region, including the southern San Bernardino, the Temecula, and, in San Diego, the La Jolla. This alternative would also encounter areas of difficult excavation in tunneled sections due to fractured rock.

High-Speed Train Alignment Options Comparison
There is not a significant difference among the proposed HST Alternative alignment options in this region based on geology.

E. LOS ANGELES TO SAN DIEGO VIA ORANGE COUNTY

Modal Alternative
In the LOSSAN region, the Modal Alternative ranked high for impacts related to seismic hazards between LAUS and Irvine, San Juan Capistrano and Camp Pendleton, and SR-52 and Santa Fe Depot in San Diego.[2] Overall, about half of the Modal Alternative would traverse areas of high seismic hazard. Additionally, the Modal alignment crosses three active faults in the southern portion of the region.

High-Speed Train Alternative
In the LOSSAN region, the HST Alternative ranked high for potential impacts related to seismic hazards along the route between LAX and LAUS. It also crosses two active faults in this area. The HST Alternative also ranked high for potential impacts related to seismic hazards between LAUS and Irvine (high-speed and conventional rail routes), in the San Juan Capistrano and Del Mar areas, and between SR-52 and Santa Fe Depot, where the alignment would cross two active faults. These high-impact areas include about half of the total rail corridor length between LAUS and San Diego and would include all existing and proposed station sites except the Irvine station site.

High-Speed Train Alignment Options Comparison
Potential slope stability problems were identified in the areas of San Juan Capistrano (east side of Trabuco Creek), Dana Point/San Clemente, Del Mar, and between SR-52 and Santa Fe Depot. Coastal bluff areas along the existing LOSSAN rail corridor in San Clemente and Del Mar rank high for potential slope instability because of the fragile nature of the bluffs. However, the options of double tracking along these existing coastal alignments were eliminated from further consideration during the LOSSAN corridor screening process. Therefore, the HST Alternative improvements would potentially result in a beneficial impact on the bluff areas in San Clemente and Del Mar by precluding further rail construction along the bluffs and removing the existing rail service from the bluff areas. This improvement would not occur under the No Project or Modal Alternatives.

[2] No Modal Alternative improvement is proposed between LAX and LAUS.

3.13.5 Mitigation Strategies

This document contains a broad program analysis that generally identifies the locations of potential geologic impact areas for the proposed alternatives. These are areas that would need further study in environmental documentation at the project level.

Mitigation for potential impacts related to geologic and soils conditions must be developed on a site-specific basis, based on the results of more detailed (design-level) engineering geologic and geotechnical studies. Consequently, geologic and geotechnical mitigation would be identified in subsequent, project-level analysis rather than at the program level. Following is an overview of general approaches to possible geologic and geotechnical mitigation.

A. GROUND SHAKING

The potential for traffic safety issues related to ground shaking during a large earthquake cannot be mitigated completely; this holds true for most vehicle transportation systems throughout California. However, some strategies are available to reduce hazards, including the following.

- The potential for collapse or toppling of superstructures such as bridges or retaining structures due to strong ground motion can be routinely mitigated by designing structures to withstand the estimated anticipated ground motions. Designs typically include additional redundancy and ductility in the structure. The design needed to withstand a certain magnitude of earthquake would be determined during subsequent stages of design and development of proposed facilities. Temporary facilities, such as shoring, would be designed considering a lower probability of seismic events.
- The potential for structural damage and resulting traffic hazard as a result of liquefaction can be mitigated through site-specific methods such as ground modification methods (soil densification) to prevent liquefaction, or structural design (e.g., deep foundations) to accommodate/resist the liquefiable zones.
- It is unlikely that the potential for HST derailment during a peak event could be mitigated by designing a track-wheel system capable of withstanding the potential ground motions in most of the project area. Existing train systems throughout California face the same challenge. However, a network of strong motion instruments has been installed throughout California and additional monitoring stations are proposed. These stations provide ground motion data that could be used with the HST instrumentation and controls system to temporarily shut down the HST operations during or after an earthquake. The system would then be inspected for damage due to ground motion and/or ground deformation and then returned to service when appropriate. This type of seismic protection is already used for many rapid transit systems in seismically active areas and has been proven effective.

B. FAULT CROSSINGS

The potential for ground rupture along active faults is one of the few geologic hazards that can rarely be fully mitigated. However, known active faults are typically monitored, and in some cases fault creep is mitigated with routine maintenance, which could include repaving or minor track re-alignment. Project design could provide for the installation of early warning systems triggered by strong ground motion associated with ground rupture. Linear monitoring systems such as time domain reflectometers (TDRs) could be installed along major highways and rail lines within the zone of potential ground rupture. These devices emit electronic information that is processed in a centralized location and could be used to temporarily control traffic and trains, thus reducing accidents. In addition, the HST Alternative has been modified in mountain crossing areas where tunnels are proposed to avoid crossing known or mapped active faults within the tunnel.

C. SLOPE STABILITY/LANDSLIDES

The potential for failure of natural and/or temporary construction slopes and retention structures can be mitigated through geotechnical investigation and review of proposed earthwork and foundation excavation plans and profiles. Based on investigation and review, recommendations would be provided for temporary and permanent slope reinforcement and protection, as needed. These recommendations would be incorporated into the construction plans. Additionally, during construction, geotechnical inspections would be performed to verify that no new, unanticipated conditions are encountered, and to verify the proper incorporation of recommendations. Slope monitoring may also be incorporated in final design where warranted.

D. AREAS OF DIFFICULT EXCAVATION

The potential for difficult excavation in areas of hard rock and faults cannot be fully mitigated, but it can be anticipated so that safety is assured, potential environmental impacts are addressed, and project schedule problems are avoided to the extent possible. This includes focusing future geotechnical engineering and geologic investigations in these areas and incorporating the findings into project construction documents, communicating with the contractors during the bid process, and monitoring actual conditions during and after construction.

E. HAZARDS RELATED TO OIL AND GAS FIELDS

Hazards related to potential migration of hazardous gases due to the presence of oil fields, gas fields, or other subsurface sources can be mitigated by following strict federal and state Occupational Safety & Health Administration (OSHA/CalOSHA) regulatory requirements for excavations, and consulting with other agencies as appropriate, such as the Department of Conservation (Division of Oil and Gas) and the Department of Toxic and Substances Control regarding known areas of concern. Mitigation measures would include using safe and explosion-proof equipment during construction and testing for gases regularly. Active monitoring systems and alarms would be required in underground construction areas and facilities where subsurface gases are present. Gas barrier systems have also been used effectively for subways in the Los Angeles area. Installing gas detection systems can monitor the effectiveness of these systems.

F. MINERAL RESOURCES

In some cases, mineral resources sites may represent valuable sources of materials that should either be completely developed prior to use for another purpose or should be avoided by proposed facilities to the extent feasible. This practice could result in realignment of proposed alignments and/or proposed relocation or modification of other proposed facilities. To mitigate the potential for significant project redesign, important mineral sites should be identified as early as possible.

3.13.6 Subsequent Analysis

As described in *Method of Evaluation of Impacts* above, this analysis was performed generally on the basis of existing data available in GIS format. The data provided in this section are intended for planning purposes, are not meant to be definitive for specific sites, and have not been independently confirmed. More detailed geological studies would be required at the project level, and would likely include subsurface exploration, laboratory testing, and engineering analyses to support detailed alignment design and mitigation of potential impacts associated with geologic and soils conditions, including seismic hazards.